WYOMING GAME AND FISH

FISH DIVISION

ADMINISTRATIVE REPORT

TITLE: Instream Flow Studies on Hobble Creek, a Bonneville Cutthroat Trout (*Oncorhynchus clarki utah*) Stream.

PROJECT IF-4093-07-9401

AUTHOR: Paul D. Dey and Thomas C. Annear

DATE: August 1994

ABSTRACT

Instream flow studies were initiated in 1993 on Hobble Creek to complement ongoing monitoring of Bonneville cutthroat trout (BRC) index streams described in a recent management plan (Remmick et al. 1993). Studies were designed to determine instream flows needed to maintain or improve BRC populations.

Physical Habitat Simulation (PHABSIM) and the Habitat Quality Index (HQI) were used to derive flow recommendations. Recommendations for the reach between the Lake Alice outlet and Coantag Creek confluences are as follows: May 1 - June 30 = 48 cfs, July 1 - September 30 = 39 cfs, and October 1 - April 30 = 30 cfs.

INTRODUCTION

Bonneville cutthroat trout (*Oncorhynchus clarki utah*) populations in Wyoming are restricted to tributaries of the Bear River - primarily the Thomas Fork and Smith's Fork watersheds. Physical, chemical, and biological characteristics of the Bear River drainage were inventoried between 1966 and 1977 (Miller 1977). Binns (1981) reviewed the distribution, genetic purity, and habitat conditions associated with populations of Bonneville cutthroat trout. Results of more recent population and habitat surveys are presented in Remmick (1981, 1987) and Remmick et al. (1993). In general, populations are limited by seasonally low flows, lack of riparian cover elements, thermal pollution arising in conjunction with low flows and reduced riparian vegetation, and silt pollution.

The Bonneville cutthroat trout was recently petitioned for listing under the Endangered Species Act. Status review was initiated in response to concerns expressed by Idaho Fish and Game, the Desert Fishes Council and the Utah Wilderness Association. A 5-year management plan for Wyoming, which was developed by the Wyoming Game and Fish Department (WGFD) in coordination with the U.S. Forest Service (USFS) and U.S. Bureau of Land Management (BLM), outlines management goals and recommends criteria for listing Bonneville cutthroat trout as threatened (Remmick et al. 1993). The plan recommends that status decisions be made after a five-year population and habitat monitoring period. Fish management and other land management practices could be significantly affected by potential listing of Bonneville cutthroat trout as Threatened and Endangered. Identification and acquisition of Instream Flow water rights is a critical element to avoid such an action on all streams containing Bonneville cutthroat trout.

One objective outlined in the management plan is to "describe existing habitat conditions, establish habitat condition objectives, and determine the impacts of past, present or proposed land management activities for all index streams by 1997." Index streams include a range of stream types for which significant habitat information and data on Bonneville cutthroat trout populations exists. In pursuit of this objective, the Instream Flow Crew initiated studies in 1993 on the following index streams: Coal Creek (Howland), Huff Creek, and Hobble Creek. This report details the results of studies on Hobble Creek and, in accordance with 1986 Instream Flow legislation, derives flow recommendations for maintaining Bonneville cutthroat trout populations.

Specifically, the primary objectives of this study were to 1) investigate the relationship between discharge and physical habitat for Bonneville cutthroat trout and, 2) determine an instream flow necessary to maintain or improve Bonneville cutthroat trout populations.

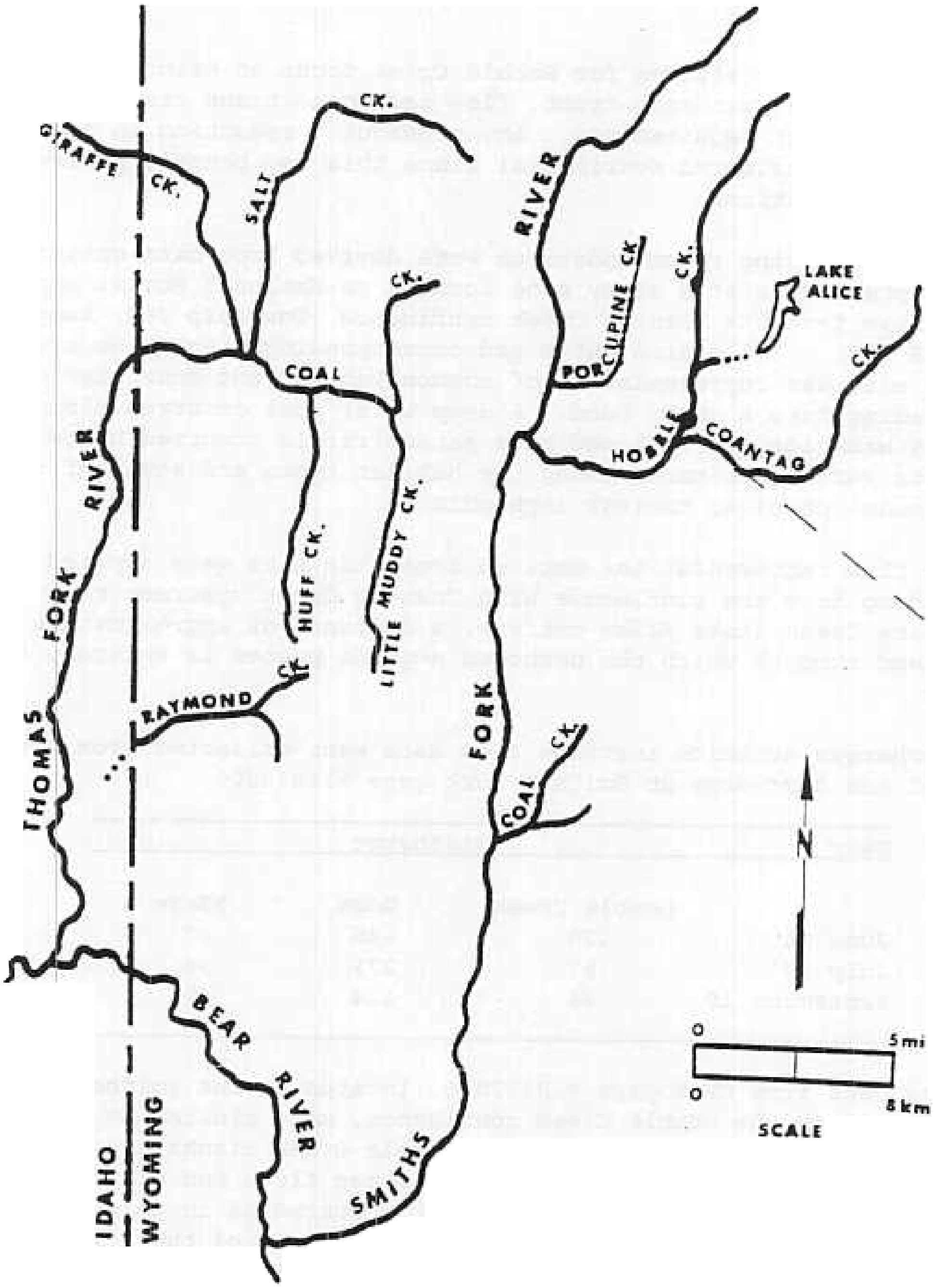
METHODS

Study Area

Hobble Creek is a major Smiths Fork River tributary in western Wyoming (Fig. 1). Occasionally constrained within a narrow valley, stream gradient is fairly high and habitat is characterized by long riffle stretches with limited pool habitat. Conversely, beaver dams are ubiquitous in regions where the stream valley broadens. These areas are commonly braided with numerous side channels and beaver runs evident. In addition to beaver-induced pool habitat, cover is associated with deep water near banks-especially on the outside of curves where undercut banks are common. Riparian vegetation is well developed with abundant willow (*Salix* sp.) and sedges (*Carex* sp.). The watershed also has locally abundant sagebrush (*Artemesia tridentata*), aspen (*Populus tremuloides*), and various conifers including subalpine fir (*Abes lasiocarpa*), lodgepole pine (*Pinus contorta latifolia*), and Engelman spruce (*Picea engelmanni*).

Bonneville cutthroat trout populations in Hobble Creek were assigned an "A" purity rating by Dr. Robert Behnke (Remmick et al. 1993). This indicates a pure stock with no evidence of hybridization. Population data collected in 1991 from 2 stations indicate an average of 278 trout/mile (Remmick et al. 1993). The average length was 6.1 in. (range = 3.5-15.4 in.).

In 1993 sampling, 23 brown trout and 1 Bonneville cutthroat trout were captured in Hobble Creek just upstream from where the Forest Service Hobble Creek campground/Lake Alice access road crosses the stream (Township 28N, Range 117 1/2W, S26, SE1/4). The single cutthroat was 11.2 in. long and the average brown trout length was 10.6 in. Conversely, at an upstream station located above the campground, only 1 brown trout (length = 6.7 in.) was captured while 22 Bonneville



Study S

Figure 1. The Smiths Fork and Thomas Fork drainages.

cutthroat were captured (avg length = 5.9 in Averaged between sites population density was 178 trout/mile.

Since management objectives for Hobble Creek focus on maintaining and improving habitat for Bonneville cutthroat trout, flow recommendations are based entirely on cutthroat trout habitat requirements. Any subsequent reduction in brown trout populations is not considered detrimental since this may benefit native Bonneville cutthroat trout populations.

Instream flow filing recommendations were derived from data collected between June 24 and September 19 at a study site located on National Forest approximately 3/4 mile upstream from the Coantag Creek confluence (Township 28N, Range 117 1/2W, Section 36, SE 1/4). Collection dates and corresponding discharges are listed in Table 1. The site was representative of common habitat and consisted of a fast riffle/run leading into a sharp bend. A deep water pool occurred along the outside of the bend, a bankside run followed by a second riffle occurred below the bend. Eight transects were distributed among the habitat types and seven of the transects were used to model physical habitat (Appendix 1).

Instream flow recommendations derived from this site were applied to the stream segment extending from the confluence with Coantag Creek upstream to the confluence with Spring Lake Creek (Lake Alice outlet), a distance of approximately 2.7 stream miles. The land through which the proposed segment passes is entirely Forest Service owned.

Table Discharges at which instream flow data were collected from Hobble Creek in 1993 and discharge at Smith's Fork gage #10032000.

Date	Discharge		
	Hobble Creek	Gage	%Gage
June 24	170	635	27
July 27	97	271	36
September 19	48	114	42

Discharge data from USGS gage #10032000, located on the Smiths Fork River 5.6 miles downstream from the Hobble Creek confluence, were plotted to gain insight into typical discharge patterns in the region. Hobble Creek discharge at the study site was estimated from regression of the three measured flows and discharge at the gage on those dates (Table 1). The flow relationship estimated in this manner is only a general approximation of the actual relationship because of the low statistical power provided by three data pairs. However, examination of the flow data indicates that estimates derived in this manner are likely more accurate than estimates based on basin areas. For example, the Hobble Creek basin above the study site is 36% of the basin area above Smiths Fork gage #10032000. Our measurements indicate that Hobble Creek flow is exactly 36% of Smiths Fork flow only at intermediate flows. At high flows, basin area estimates overpredict Hobble Creek discharge while at low flows Hobble Creek discharge is underestimated.

Methodologies

The Physical Habitat Simulation (PHABSIM) system was used to model the quantity of physical habitat (depth and velocity) available to cutthroat trout over a range of discharges. This methodology was developed by the Instream Flow Service Group of the U.S. Fish and Wildlife Service (Bovee and Milhous 1978) and is the most widely used approach for assessing instream flow relationships between fish and physical habitat (Reiser et al. 1989).

Depth, velocity, and substrate were measured along eight transects (transect locations described above) according to techniques outlined in Bovee and Milhous (1978). Measurements were taken on the dates listed in Table 1. Hydraulic calibration techniques and modeling options outlined in Milhous et al. (1984) and Milhous et al. (1989) were employed to incrementally estimate physical habitat between 20 and 200 cfs. Precision declines outside this range; however, the modeled range easily accommodates the range of typical Hobble Creek flows.

The PHABSIM model utilizes empirical relationships between physical variables (depth, velocity, and substrate) and suitability for fish to derive an estimate of weighted usable area (WUA) at various flows. Suitability curves for spawning Bonneville cutthroat trout were developed from data collected in 1994 from Huff Creek (Appendix 2). General cutthroat trout curves (Appendix 2, Bovee 1978) were used to determine discharge-physical habitat relationships for the fry, juvenile and adult life stages.

Critical Bonneville cutthroat trout life stages in Hobble Creek and time periods of importance are identified in Table 2. Critical life stages are those life stages most sensitive to environmental fluctuations. Population integrity is sustained by providing adequate flow for critical life stages. In many cases, Rocky Mountain stream populations are constrained by spawning and young (fry and juvenile) life stage habitat bottlenecks (Nehring and Anderson 1993). On Hobble Creek, observations indicate that spawning habitat is likely a critical factor influencing trout populations. Furthermore, it is likely that maintenance of adult survival via adequate physical habitat during the winter (October-April) is important for population stability.

According to information in Binns (1981), spawning in Hobble Creek (elevation 7300 ft) should peak between about May 12 and June 3. To provide latitude for inter-annual flow and temperature variation, the spawning period should be recognized as May 1 to June 30. Even if spawning is completed by June 1, maintaining flows at a selected level throughout June will benefit incubation. The PHABSIM system was used to derive flow recommendations for spawning Bonneville cutthroat trout from May 1 to June 30 and adult cutthroat trout from October 1 to April 30 (Table 2). Physical habitat for fry and juveniles was also determined with the PHABSIM system and these data are included for reference.

Table 2. Bonneville cutthroat trout life stages considered in development of instream flow recommendations for Hobble Creek. Numbers indicate method used to determine flow requirements.

LIFE STAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Adult	2	2	2	2			1	1	1	2	2	2
Spawning					2	2						

1 - Habitat Quality Index
2 - PHABSIM

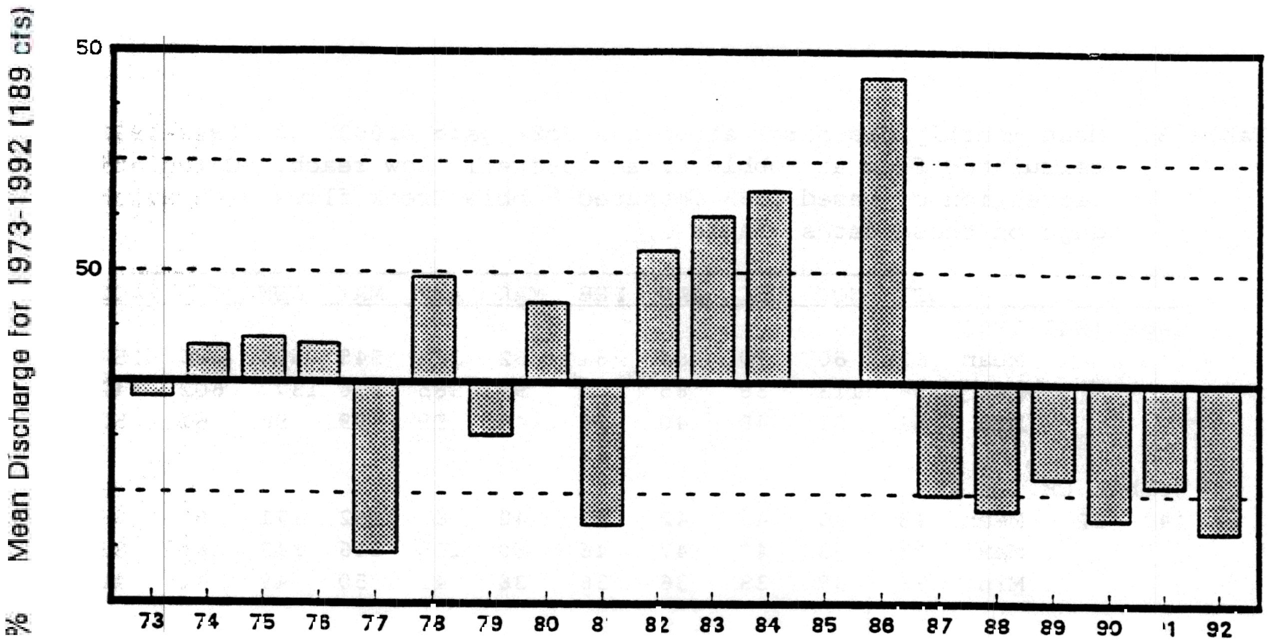
The Habitat Quality Index (HQI; Binns and Eisermann 1979) was used to estimate trout production over a range of late summer flow conditions. This model was developed by WGFD and received extensive testing and refinement. It has been reliably used in Wyoming for assessment of habitat gains or losses associated with projects that modify instream flow regimes. The HQI model includes nine attributes addressing biological, chemical, and physical aspects of trout habitat. Results are expressed in trout Habitat Units (HUs), where one HU is defined as the amount of habitat quality that will support 1 pound of trout. HQI results were used to identify the average flow needed to maintain or improve existing levels of trout production between July 1 and September 30 (Table 2).

In the HQI analysis habitat attributes measured at various flow events are assumed to be typical of mean late-summer flow conditions. Under this assumption, HU estimates can be extrapolated through a range of potential late summer flows (Conder and Annear 1987). Hobble Creek habitat attributes were measured on the same dates that PHABSIM data were collected (Table 1). Some attributes were mathematically derived to establish the relationship between discharge and trout production at discharges other than those measured. Other data were obtained by referencing Smiths Fork River USGS gage #10032000. Average daily flow was estimated at 70 cfs and Annual Stream Flow Variability was calculated based on an estimated average peak flow of 247 cfs.

RESULTS AND DISCUSSION

Discharge

Southwest Wyoming streams typically exhibit both annually and seasonally variable flows. On the annual scale, extended drought conditions, such as those in 1987-1992, are not uncommon. Seasonally, snowpack-derived flows are often quite high through June and drop to low levels in late fall and winter. For example, average June discharge in the upper Smiths Fork River was nearly 1,400 cfs in 1986 (Table 3). Flows averaged less than 100 cfs throughout the winter. Annual discharge in 1986 was the highest that occurred in the last 20 years while discharge in 1992 was low and followed 5 years of drought (Fig. 2).



Fi Per eviatio ischarg ;miths Fork Ri gag

00 :000 from 0 yı mean har '7' 99 cf

Table 3 Mean monthly discharge at Smiths Fork gage #10032000 (1943-1992) and calculated flow at Hobble Creek instream flow reach. Calculations are regression of based 1993 measured Hobble Creek flows with discharge at the gage on those dates (Table 1).

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Gage 1943-1992													
	Mean	92	80	70	64	61	62	162	545	630	266	154	109
	Max	156	113	88	85	83	99	385	956	1377	602	242	166
	Min	51	51	48	40	38	40	59	99	96	61	55	52
Hobble Ck													
'43-'92	Mean	48	46	43	42	41	42	64	152	171	88	63	52
	Max	63	53	47	47	46	50	115	246	342	165	83	65
	Min	39	39	38	36	36	36	41	50	49	41	40	39
	Mean	50	53	47	42	41	50	101	209	342	142	73	65
	Max	57	55	52	47	41	78	189	427	484	199	99	77
	Min	47	51	44	39	39	41	76	110	207	103	61	58
	Mean	46	45	44	42	40	44	62	92	69	53	46	43
	Max	49	49	46	45	42	49	87	100	82	59	48	45
	Min	45	41	40	39	39	42	49	84	59	48	44	42

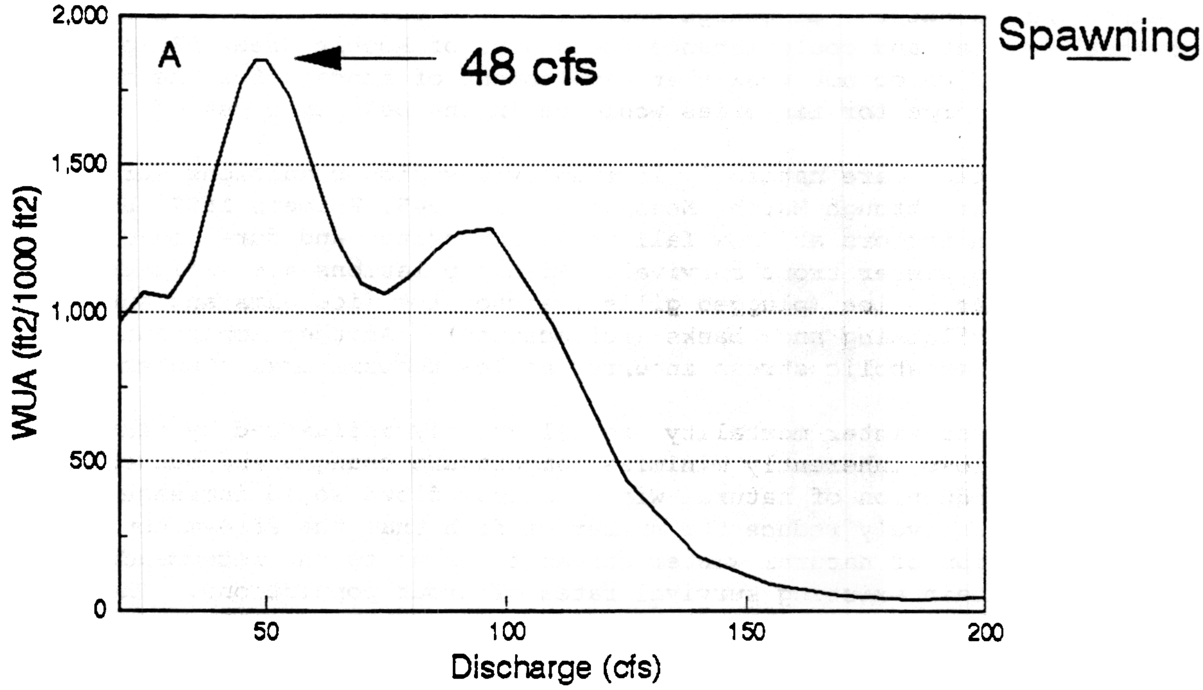
Flow measurements indicate that Hobble Creek is less variable on an annual cycle than Smiths Fork; flow was only 27% of gage flow at high discharge and 42% of gage flow at low discharge (Table 1). Hobble Creek's relatively stable flows result from several beaver dams and the stable flows provided by the Lake Alice outlet. Discharge estimates indicate that average flows in Hobble Creek are lowest in February (41 cfs) and highest in June (171 cfs).

PHABSIM Analysis

Weighted usable area estimates for four life stages of cutthroat trout are illustrated in Figure 3. PHABSIM analysis indicates that a flow of 48 cfs maximizes physical habitat for spawning (Fig. 3A). Existing average flows during this period range from 152 to 171 cfs (Table 3). An instream flow of 48 cfs is recommended for the period May 1 to June 30.

Fry and juvenile physical habitat appear to decrease almost linearly with increasing discharge (Fig. 3B). The PHABSIM model is insensitive to increases in off-channel areas which occur at high flows (approximately those discharges greater than 150 cfs). Backwater areas flooded during high spring discharges provide excellent habitat for fry well into the summer months. Therefore, the absolute level of fry physical habitat was likely underestimated.

Adult physical habitat peaks at 30 cfs and drops significantly at flows greater than 65 cfs (Fig. 3B). Existing average flows during winter range from 41 to 64 cfs (Table 3). An instream flow of 30 cfs is recommended for the period October 1 to April 30.



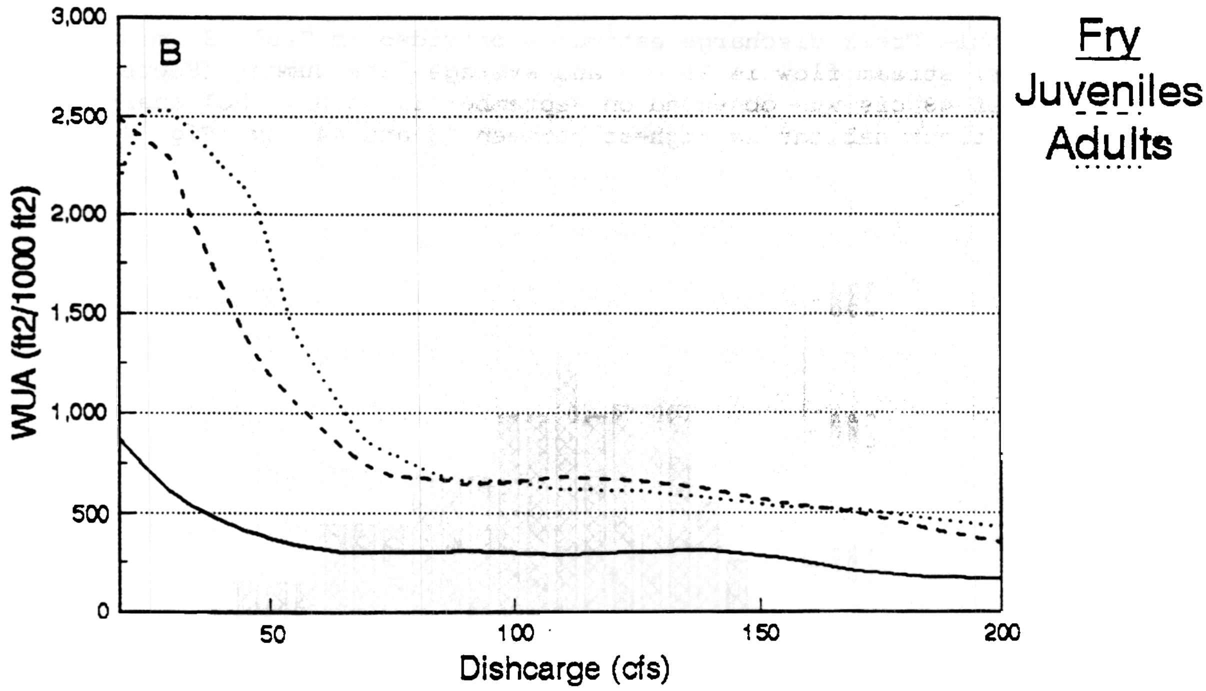


Figure 3. (A) Spawning Weighted Usable Area (WUA) on Hobble Creek.

(B) Fry, juvenile, and adult WUA.

Reductions in natural discharge would increase the quantity of adult and spawning physical habitat and could enhance the status of Hobble Creek BRC populations. Though beneficial, we do not feel that development of storage for the sole purpose of modifying discharge for fisheries would be in the best interest of the State.

Trout populations are naturally limited by low flow conditions during the winter months (October through March; Needham et al. 1945, Reimers 1957, Butler 1979, Kurtz 1980). Such factors as snow fall, cold intensity, and duration of cold periods can influence winter trout survival. Fish populations are influenced through the effects of frazile ice (plugged gills), anchor ice (ice dams and subsequent stranding), and collapsing snow banks (suffocation). Another important consideration is excessive metabolic stress incurred at low temperatures (Cunjak 1988).

These causes of winter mortality are all greatly influenced by winter flow levels. Higher flows inherently minimize temperature changes and subsequent trout mortality. Any reduction of natural winter stream flows would increase trout mortality and effectively reduce the number of fish that the stream could support. Therefore protection of natural winter stream flows up to the recommended flow is necessary to maintain existing survival rates of trout populations. The recommended instream flow of 30 cfs for the period October 1 to April 30 will maintain present levels of Bonneville cutthroat trout production.

Habitat Unit Analysis

Based on Hobble Creek discharge estimates provided in Table 3, minimum late summer (September) stream flow is 39 cfs and average late summer (September) flow is 52 cfs. A flow of 48 cfs was observed on September 19, 1993. HQI analyses indicate that late summer trout habitat is highest between 39 and 44 cfs (Fig. 4). Under

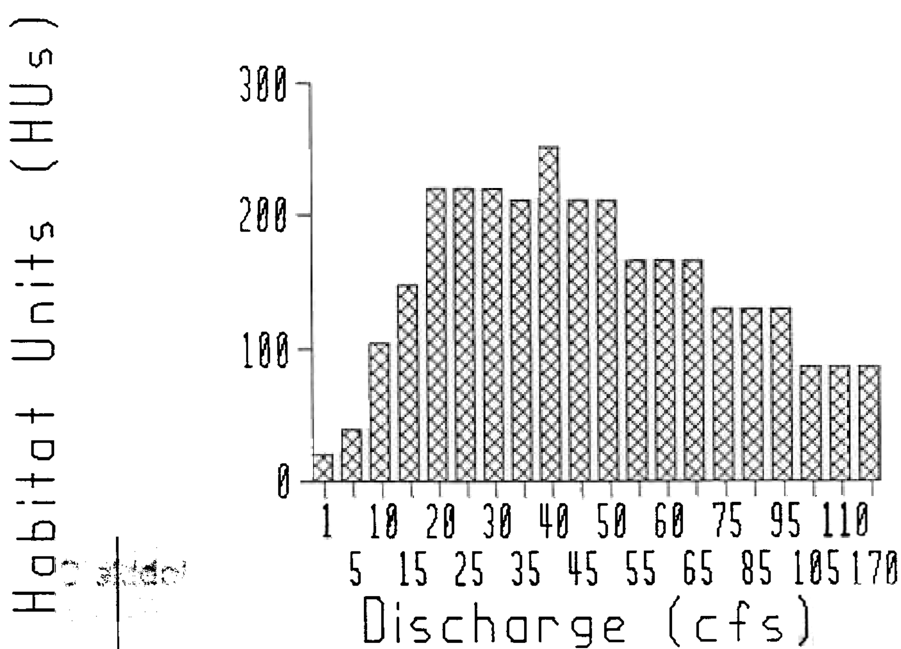


Figure 4 Potential trout habitat units at several late summer flow levels in Hobble Creek.

existing late summer conditions (48 cfs) the stream supports 212 HUs. Late summer discharges less than 15 cfs or greater than 95 cfs would result in significant trout habitat losses. These habitat losses would be due primarily to less suitable velocities and low late summer stream flows.

In light of the 5-year Management Plans' emphasis on increasing Bonneville cutthroat trout populations in areas where they are low (Remmick et al. 1993), instream flow recommendations should provide for increased or maximized BRC habitat and hence maintain or improve populations. This strategy is appropriate considering the species Category II status and represents a legitimate effort to avoid listing of the species under the Threatened and Endangered Species Act. Listing of the Bonneville cutthroat trout may compromise state fisheries and land management opportunities in the Bear River drainage.

Based on the results of the HQI analysis, an instream flow of 39 cfs is recommended to maintain existing levels of trout production between July 1 and September 30.

Flow Recommendations

Based on the analyses and results outlined above, the instream flow recommendations in Table 4 will maintain or improve the existing Hobble Creek Bonneville cutthroat trout fishery. These recommendations apply to a 2.7 mile segment of Hobble Creek extending downstream from the mouth of Spring Lake Creek (Lake Alice outlet; T28N, R117 1/2W, S24, NE1/4) to the mouth of Coantag Creek (T28N, R117 1/2W, S36, SE1/4).

Table 4 Summary of instream flow recommendations to maintain or improve the existing Bonneville cutthroat trout fishery in Hobble Creek.

Time Period	Instream Flow Recommendation (cfs)
May 1 to June 30	48
July 1 to September 30	39
October 1 to April 30	30

This analysis does not consider periodic requirements for channel maintenance flows. Because this stream is presently unregulated, channel maintenance flow needs are adequately met by natural runoff patterns. If the stream is regulated in the future, additional studies and recommendations may be appropriate for establishing flow requirements for channel maintenance.

LITERATURE CITED

Annear, T.C. and A.L. Conder. 1984. Relative bias of several fisheries instream flow methods. North American Journal of Fisheries Management 4:531-539.

Binns, N.A. 1981. Bonneville cutthroat trout Salmo clarki utah in Wyoming. Wyoming Game and Fish Department, Fisheries Technical Bulletin No. 5.

Binns, N.A. and F. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108:215-228.

Bovee, K. 1978. Probability of use criteria for the family Salmonidae. Instream Flow Information Paper No. 4. FWS/OBS-78107.

Bovee, K. and R. Milhous. 1978. Hydraulic simulation in instream flow studies: theory and technique. Instream Flow Information Paper 5, FWS/OBS-78/33, Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service. Fort Collins, Colorado.

Butler, R. 1979. Anchor ice, its formation and effects on aquatic life. Science in Agriculture, Vol XXVI, Number 2, Winter, 1979.

Conder, A.L. and T.C. Annear. 1987. Test of weighted usable area estimates derived from a PHABSIM model for instream flow studies on trout streams North American Journal of Fisheries Management 7:339-350.

Cunjak, R.A. 1988. Physiological consequences of overwintering in streams; the cost of acclimatization? Canadian Journal of Fisheries and Aquatic Sciences 45:443-452.

Kurtz, J. 1980. Fishery management investigations. - a study of the upper Green River fishery, Sublette County, Wyoming (1975-1979). Completion Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1984. User's guide to the physical habitat simulation system. Instream Flow Paper 11, FWS/OBS-81/43, U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Milhous, R.T., M.A. Updike, and D.M. Schneider. 1989. Physical habitat simulation system reference manual - version II. Instream Flow Information Paper No. 26. U.S. Fish and Wildlife Service, Biol. Rep. 89(16).

Miller, D.D. 1977. Comprehensive survey of the Bear River drainage. Wyoming Game and Fish, Administrative Report.

Needham, P., J. Moffett, and D. Slater. 1945. Fluctuations in wild brown trout populations in Convict Creek, California. Journal of Wildlife Management 9:9-25.

Nehring, R. 1979. Evaluation of instream flow methods and determination of water quantity needs for streams in the state of Colorado. Colorado Division of Wildlife, Fort Collins.

Nehring, B.R. and R.M. Anderson. 1993. Determination of population-limiting critical salmonid habitats in Colorado streams using the Physical Habitat Simulation System. Rivers 4:1-19.

Reimers, N. 1957. Some aspects of the relation between stream foods and trout survival. California Fish and Game 43:43-69.

Reiser, D.W., T.A. Wesche, and C. Estes. 1989. Status of instream flow legislation and practices in North America Fisheries 14(2):22-29.

Remmick, R. 1981. A survey of native cutthroat populations and associated stream habitats in the Bridger-Teton National Forest. Wyoming Game and Fish Department, Administrative Report.

Remmick, R. and N.A. Binns. 1987. Effect of drainage wide habitat management on Bear River Cutthroat trout (*Salmo clarki utah*) populations in the Thomas Fork drainage, Wyoming. Wyoming Game and Fish Department, Administrative Report.

Remmick, R., K. Nelson, G. Walker, and J. Henderson. 1993. Bonneville cutthroat trout inter-agency five year management plan (1993-1997)

Appendix 1. Reach weighting used for PHABSIM analysis.

STAID	LENGTH	WEIGHT	PERCENT	HABITAT TYPE
0.00	12.00	1.00	5.58	RIFFLE
24.00	24.00	1.00	11.16	RUN
48.00	21.00	1.00	9.77	POOL
66.00	18.00	1.00	8.37	POOL
84.00	22.50	1.00	10.47	RUN
111.00	117.50	0.56	30.47	RIFFLE
215.00			24.19	RIFFLE

Appendix 2. Suitability index data used for PHABSIM analysis. Adult, juvenile and fry data are from Bovee 1978. Spawning index data is from Huff Ck., 1994.

FRY

VELOCITY	WEIGHT
0.00	0.00
0.10	0.00
0.15	0.09
0.25	0.38
0.30	0.70
0.35	0.90
0.40	0.99
0.45	1.00
0.50	0.99
0.55	0.90
0.60	0.82
0.70	0.69
0.75	0.63
0.80	0.58
0.90	0.50
1.00	0.43
1.25	0.30
1.50	0.20
1.60	0.17
1.70	0.14
1.85	0.10
2.00	0.08
2.20	0.05
2.30	0.04
2.50	0.03
2.75	0.02
2.90	0.00
100.00	0.00

DEPTH	WEIGHT
0.00	0.00
0.40	0.00
0.50	0.12
1.00	0.64
1.05	0.71
1.10	0.77
1.15	0.88
1.20	0.96
1.25	0.99
1.30	1.00
1.55	1.00
1.60	0.98
1.65	0.92
1.70	0.85
1.80	0.74
1.90	0.66
2.00	0.59
2.10	0.54
2.20	0.50
2.30	0.46
2.45	0.41
2.55	0.39
2.70	0.37
2.85	0.36
3.05	0.34
3.20	0.32
3.30	0.31
3.50	0.26
3.70	0.20
3.80	0.16
3.90	0.10
3.95	0.06
4.00	0.00
100.00	0.00

SUBSTRATE	WEIGHT
0.00	0.00
3.00	0.00
3.20	0.02
3.40	0.05
3.60	0.08
3.70	0.10
3.80	0.13
4.00	0.18
4.20	0.24
4.40	0.33
4.50	0.39
4.60	0.45
4.70	0.53
4.80	0.63
4.90	0.76
5.00	0.97
5.10	1.00
5.20	1.00
5.30	0.96
5.90	0.76
6.00	0.73
6.30	0.58
6.60	0.45
6.90	0.33
7.20	0.23
7.50	0.14
8.00	0.00
100.00	0.00

JUVENILE

VELOCITY	WEIGHT
0.00	0.00
0.10	0.00
0.20	0.12
0.30	0.30
0.40	0.59
0.45	0.83
0.50	0.95
0.55	0.98
0.65	1.00
1.05	1.00
1.15	0.99
1.25	0.97
1.40	0.94
1.50	0.91
1.60	0.87
1.65	0.85
1.70	0.82
1.75	0.77
1.85	0.56
1.90	0.46
1.95	0.42
2.05	0.32
2.10	0.28
2.15	0.25
2.30	0.19
2.40	0.16
2.65	0.12
2.75	0.10
2.85	0.07
3.00	0.00
100.00	0.00

DEPTH	WEIGHT
0.00	0.00
0.50	0.00
0.65	0.08
0.70	0.10
0.80	0.18
0.90	0.26
0.95	0.32
1.10	0.50
1.20	0.68
1.30	0.94
1.35	0.98
1.45	1.00
1.50	1.00
1.60	0.98
1.65	0.93
1.70	0.87
1.75	0.82
1.80	0.78
1.95	0.70
2.10	0.62
2.25	0.56
2.70	0.41
3.00	0.28
3.30	0.17
3.55	0.10
3.65	0.07
3.75	0.05
3.90	0.03
4.15	0.00
100.00	0.00

SUBSTRATE	WEIGHT
0.00	0.00
4.00	0.00
4.20	0.08
4.30	0.13
4.40	0.18
4.50	0.24
4.60	0.30
4.70	0.37
4.80	0.45
5.00	0.63
5.10	0.70
5.20	0.75
5.30	0.80
5.50	0.87
5.70	0.94
5.90	0.98
6.00	1.00
6.10	0.97
6.40	0.84
6.60	0.74
7.00	0.48
7.20	0.36
7.40	0.26
7.60	0.19
7.80	0.11
8.00	0.06
100.00	0.00

Appendix 2. cont.

ADULTS

VELOCITY	WEIGHT
0.00	0.00
0.10	0.00
0.25	0.31
0.35	0.49
0.45	0.61
0.55	0.70
0.70	0.81
0.80	0.87
0.90	0.92
1.00	0.96
1.10	0.98
1.20	1.00
1.70	1.00
1.80	0.98
1.85	0.97
1.90	0.95
2.00	0.90
2.15	0.80
2.25	0.71
2.35	0.59
2.40	0.51
2.50	0.30
2.55	0.17
2.60	0.11
2.65	0.08
2.70	0.06
2.80	0.03
2.85	0.02
3.00	0.00
100.00	0.00

DEPTH	WEIGHT
0.00	0.00
1.00	0.00
1.05	0.02
1.10	0.06
1.15	0.14
1.20	0.68
1.25	0.88
1.30	0.94
1.35	0.96
1.40	0.98
1.55	1.00
1.75	1.00
1.85	0.97
1.95	0.92
2.00	0.88
2.05	0.82
2.10	0.78
2.20	0.71
2.30	0.65
2.45	0.58
2.60	0.53
2.75	0.49
2.95	0.44
3.25	0.38
3.60	0.32
4.75	0.17
5.00	0.13
5.15	0.10
5.25	0.08
5.35	0.05
5.50	0.00
100.00	0.00

SUBSTRATE	WEIGHT
0.00	0.00
4.00	0.00
4.20	0.08
4.30	0.13
4.40	0.18
4.60	0.32
4.70	0.42
4.80	0.55
4.90	0.70
5.00	0.93
5.10	0.97
5.20	0.99
5.40	1.00
6.70	1.00
6.80	0.99
6.90	0.96
7.00	0.91
7.10	0.78
7.20	0.66
7.30	0.57
7.40	0.50
7.50	0.44
7.70	0.36
7.80	0.32
7.90	0.29
8.00	0.26
8.50	0.16
9.00	0.00
100.00	0.00

SPAWNING

VELOCITY	WEIGHT
0.00	0.00
0.10	0.00
0.20	0.01
0.32	0.02
0.45	0.03
0.60	0.06
0.76	0.11
0.91	0.19
1.01	0.25
1.10	0.32
1.22	0.44
1.32	0.54
1.41	0.64
1.50	0.74
1.60	0.83
1.72	0.93
1.81	0.98
1.91	1.00
1.97	1.00
2.09	0.96
2.19	0.91
2.31	0.80
2.41	0.71
2.50	0.60
2.62	0.47
2.72	0.38
3.20	0.00
100.00	0.00

DEPTH	WEIGHT
0.00	0.00
0.10	0.03
0.15	0.08
0.20	0.15
0.25	0.30
0.30	0.51
0.35	0.70
0.40	0.90
0.45	1.00
0.50	1.00
0.55	0.82
0.60	0.64
0.65	0.41
0.70	0.23
0.75	0.12
0.80	0.05
1.00	0.01
1.50	0.00
100.00	0.00

SUBSTRATE	WEIGHT
0.00	0.00
4.10	0.00
4.20	1.00
5.60	1.00
5.70	0.00
100.00	0.00